RESEARCH DEPARTMENT

Field-store standards conversion: a controlled r.f. switch

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SUMMARY

This report describes the development of a type of r.f. switch unit which is intended to control the r.f. signal routing in an experimental field-store standards converter. The switches are actuated by uni-directional control signals and contain built-in amplification so that they can be adjusted to have zero loss.

1. INTRODUCTION

1.1. General Description

Fig. 1 shows applications of three types of switch which are used to control the signal routing through a delay path D or along a by-pass route in the main store of a field-store standards converter.[1] In practice a large number of delays and by-pass routes are involved and in each case the choice of switch type depends upon the particular application. The different forms of switch are shown in Figs. 1(*a*), 1(*b*) and 1(*c*). The first two switches are one-pole, two-way switches and are identical except that the signal directions are reversed. The third type of switch (*c*) is a cross-over or transposing switch.

From a comparison of Figs. 1(*a*), 1(*b*) and 1(*c*), it will be seen that the cross-over or transposing form of switch shown in Fig. 1(*c*) is capable of performing any of the operations performed by the other two. In the interests of both expediency and experimental flexibility, therefore, it was decided that, for the time being at least, a single type of r.f. switch would be developed in the form shown in Fig. 1(*c*). This type of switch would be used whichever switching operation was required; if it were later decided to use switches of the simpler forms shown in Figs. 1(*a*) and 1(*b*), then the design problems would not be difficult since all the important development work would have been carried out.

The design of the switch was based upon two (complementary) types of basic switching element, one operated by a positive control signal, and the other operated by a negative control signal. As

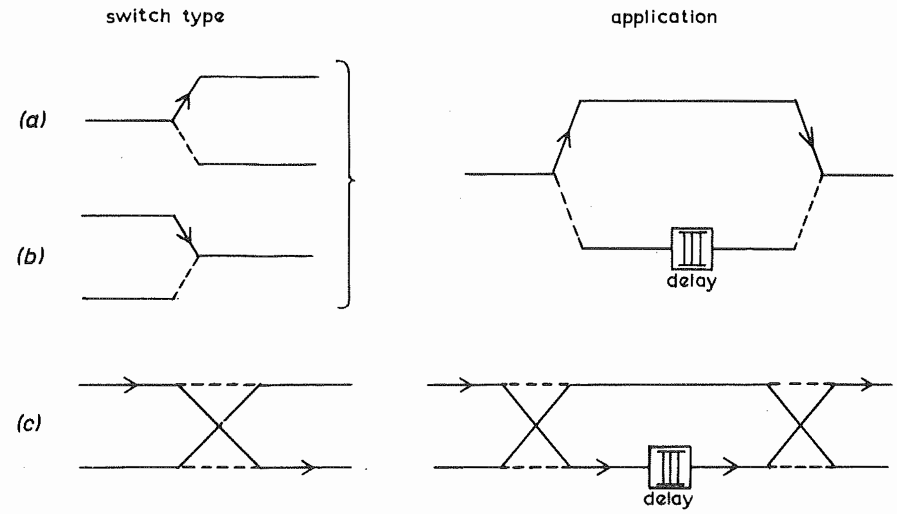

Fig. 1 - Types of switch and their applications in the main store of a field-store standards converter

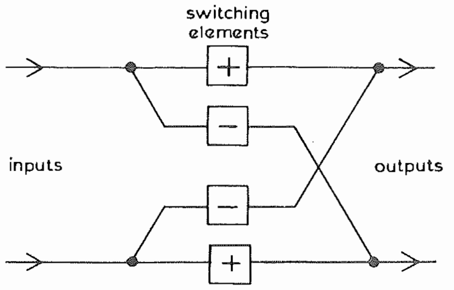

Fig. 2 - Block schematic of switch in Fig. 1(c)
+ or - : Polarity of unidirectional control signal

illustrated in Fig. 2, the switches are formed by joining four such elements (two of each kind) at their inputs and outputs respectively so as to provide two separate inputs and two separate outputs.

1.2. Specification of Switch Performance

Each basic switching element has to meet the following specification:

(1) The elements should be capable of switching modulated r.f. signals having frequencies within the range 25 MHz to 35 MHz. The response/frequency requirements over this band are very stringent and there should not be a variation of more than 1 dB when twenty switches are cascaded.

(2) The level of all signals to be switched is 0·5 V p-p across 75 Ω input and output impedances.

(3) The voltage-gain of each element should be unity and adjustable over a range of approximately ±10%.

(4) The switching voltages and currents should be kept as low as possible commensurate with adequate performance.

(5) The signal to be switched consists of a frequency-modulated constant-amplitude carrier (for the picture signals) with 4 μs sync-pulse periods of zero carrier. The switches are required to operate during the synchronizing periods; a switching time greater than 1 μs is therefore undesirable, but equally, a very short switching time is unnecessary.

(6) The level of any unwanted r.f. signal breakthrough should not exceed -60 dB with respect to that of the wanted signal. The unwanted r.f. signal is generally a combination of two effects:

(i) Breakthrough due to inefficient switching action (expressed as an ON/OFF ratio).
(ii) Reactive crosstalk between components of switching elements in close proximity, or crosstalk due to unsatisfactory de-coupling (expressed as a crosstalk ratio).

(7) The level of all unwanted components of the control signals in the output should be less than 10% of that of the r.f. signal.

(8) The group-delay variation over the band should be <5 ns when twenty switch units are cascaded.

2. DESCRIPTION OF DESIGN

2.1. Basic Switching Element

The circuit of each switching element is based upon the balanced diode and transformer circuit seen in Fig. 3. The switch-control signal is applied through R1 and is fed to the centre tap of T1. If (in the circuit shown) the control signal is negative, D1 and D2 will be biased ON while D3 and D4 will be biased OFF. An r.f. path is then established through D1 and D2, and an r.f. signal applied to T1 will appear at T2. When the switching polarity is

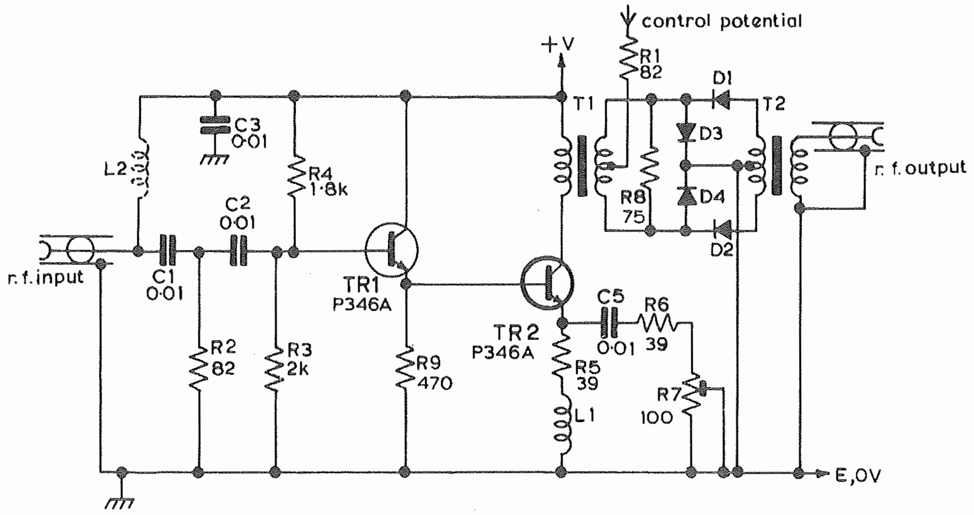

Fig. 3 - Basic switching element

reversed, D3 and D4 will be ON, while D1 and D2 will be biased OFF. D3 and D4 will then present a low impedance to earth, and D1 and D2 a high impedance to r.f. signals. Hence little signal will appear across T2. In the complementary form of switching element, the diode connexions are reversed, thereby reversing the ON and OFF conditions. The circuits of the two forms of switching element are otherwise identical.

It is possible to minimize the loss due to the diodes by adjusting the turns ratio of T1 and T2 so that D1 and D2 operate in a high-impedance circuit. However, this results in a poor high-frequency response, since the reactances of T1 and T2 are then more prominent at high frequencies. T1 and T2 were therefore constructed with a 1 : 1 turns ratio, and the resulting attenuation of about 2 dB in the diode section of each switching element was compensated by means of the transistor amplifier also seen in Fig. 3. The amplifier uses an npn transistor TR2 in a grounded-emitter stage which is preceded by an emitter-follower stage TR1. This type of amplifier was chosen since it is easy to control accurately the input and output impedances, and it can provide a gain which is a little in excess of unity when using heavy emitter feedback. The emitter-follower stage presents a sufficiently low impedance to ensure that the effect of the reactance between the base and earth of TR2 is negligible over the required passband. The input impedance of TR1 itself is thus very high and R2, together with R3 and R4, determine the input impedance of the device. The network in the emitter of TR2 provides negative feedback which is variable over a limited range for the purpose of gain control. L1 has the effect of compensating approximately for the capacitance that appears between the emitter of TR2 and ground which would otherwise cause small variations in the response/frequency characteristic when adjustments of gain were made.

2.2. Power Supply

The power for the amplifiers of each switch can if necessary be inserted into the r.f. input cable at some external point and recovered within the switch via the r.f. choke L2 shown in Fig. 3.

2.3. Common Inputs and Outputs

Because the complete crossover or transposing switch has inputs and outputs which are shared by different switching elements (see Fig. 2), it is important that the input and output impedances of each switch should be independent of its state.

Fig. 4(*a*) shows the input signal fed to the emitter-followers (first stages) of two amplifiers. As was stated in Section 2.1, the input impedance of each emitter-follower is very high and a satisfactory 75 Ω resistive input impedance is formed by a single terminating resistor R2.

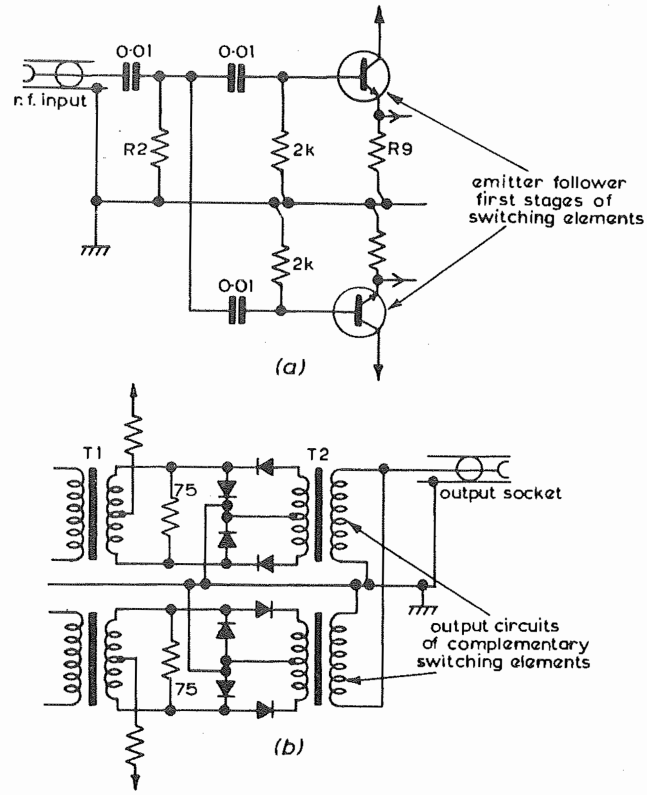

Fig. 4 - Method of obtaining
(*a*) Common input (*b*) Common output

The output impedance of each switching element is accurately 75 Ω when the switch is ON, but very high when OFF. Thus if the output circuit of two complementary switching elements are connected in parallel as shown in Fig. 4(*b*), one provides a source impedance of 75 Ω, while the other is effectively open circuit; thus a constant output impedance is obtained.

2.4. Mechanical Design

A photograph of a completed switch with the cover removed is shown in Fig. 5. It will be seen that the switching elements run lengthways down the body of the unit and are separated from each other by a brass screen of cruciform section.

3. PERFORMANCE

The performance of the switch will be described under the following headings:

(1) Unwanted signal rejection.

(2) Response/frequency and group delay/frequency characteristics.

(3) Gain as a function of supply voltage.

(4) Overload characteristic.

(5) Switch-control voltage.

(6) Spurious switching pulses.

3.1. Unwanted Signal Rejection

A number of separate switching elements were constructed and measurements of their ON/OFF ratios made. These tests revealed that the ON/OFF ratio of each element is greater than 65 dB, and a total rejection greater than 60 dB is obtained in each complete switch containing four elements.

3.2. Response/Frequency and Group-Delay/Frequency Characteristics

The specification of performance given in Section 1.2 requires an accurately uniform response/frequency characteristic within the prescribed passband from 25 MHz to 35 MHz. This was achieved by designing the circuits to include a much wider band of frequencies (from about 1 MHz to 60 MHz) with the wanted passband occupying the central region of uniform response. This principle was found to be successful, although some difficulty was experienced with the effects of transformer core losses, which increase with frequency and cause a slight "tilt" across the passband; the difficulty was overcome by the use of a suitable number of turns per winding. The performance in respect of group-delay variations over the passband was checked and found to be well inside the specified limits.

3.3. Gain as a Function of Supply Voltage

Variations in the supply voltage, about the design value of 5 V, resulted in gain variations of 0·25 dB per volt. It was concluded that negligible variation in gain would result when using a conventional regulated power supply.

3.4. Overload Characteristic

The required output level of 0·5 V p-p could be increased to 2 V p-p before non-linearity was detectable by observation of the output waveform. Indirect measurements of non-linearity were also made using intermodulation techniques. These measurements indicated that the greatest departure from amplitude linearity over the working range is less than 0·05%.

3.5. Switch-Control Voltage

It was found that, for reliable and stable performance, each diode circuit requires a minimum total operating current of about 50 mA. This current is fed to each switching element through a series isolating resistor of 82 Ω (R1, Fig. 3) which also provides isolation between the signal circuits of each switching element. Under these conditions, the minimum switching voltage for reliable and stable operation was found to be about 5 V, and an operating voltage of 6 V was decided upon to ensure an adequate margin of reliability.

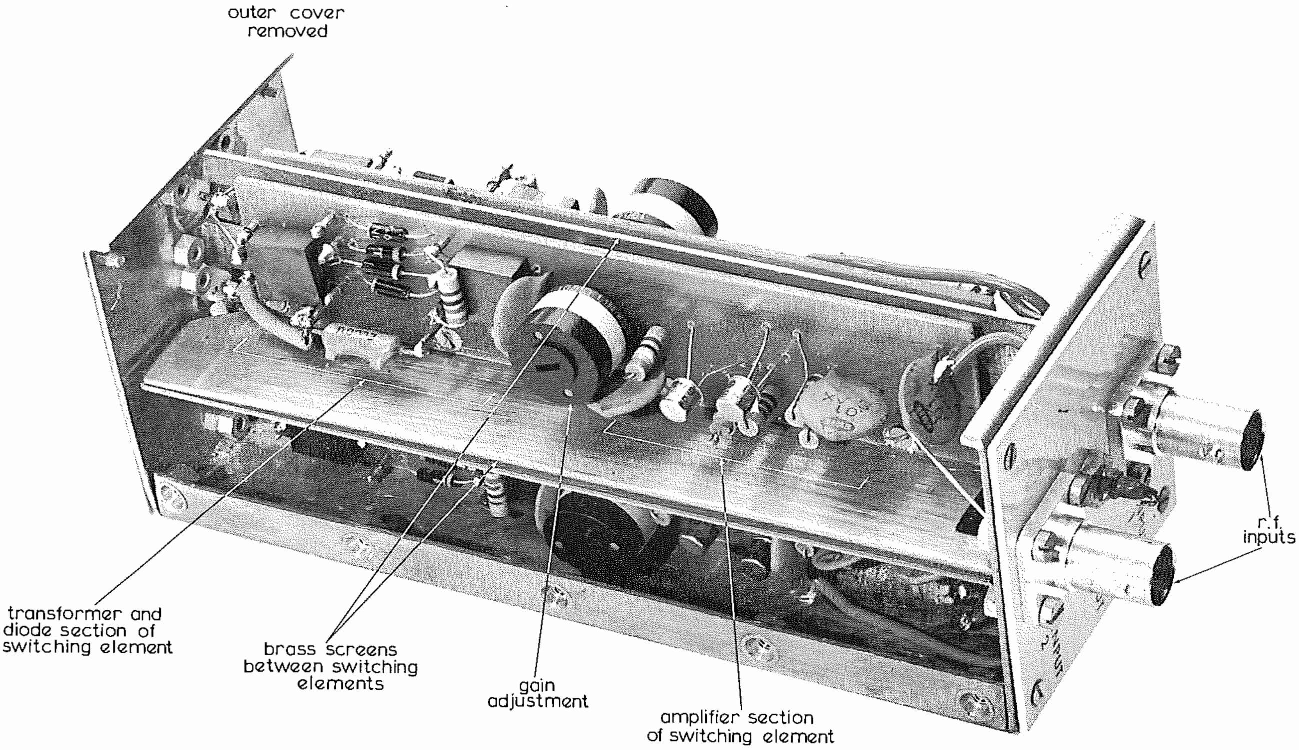

Fig. 5 - A completed switch

3.6. Spurious Switching Pulses

A perfectly balanced diode and transformer circuit should produce no component of the control signal at the output. In practice, it was found that there were almost always small pulses added to the output which were traced either to imperfectly balanced diodes or to imperfectly balanced transformers. The pulses were, however, never observed to have magnitudes greater than 10% of the r.f. signal amplitude. Because of their limited spectrum, pulses of this amplitude make a negligible contribution to the r.f. signal output.

4. CONCLUSIONS

A switch has been developed which is capable of performing all the radio-frequency switching operations required in the main store of an experimental field-store standards converter. Development has been restricted to a crossover or transposing r.f. switch, but design information now exists for the manufacture of changeover r.f. switches. Tests have shown the design to be satisfactory.

5. REFERENCE

1. WHARTON, W. *and* DAVIES, R.E. 1966. Field store standards conversion - conversion between television signals with different field frequencies using ultrasonic delays. *Proc.Instn elect. Engrs.*, **113**, 6, pp. 989 - 996.

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